Production, Transmission and Detection of Cherenkov Light in Oil

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Goals

- Review and Document Known Properties of Optical Model

- Catalog issues to be resolved

- Discover anything interesting which comes along

Production of Cherenkov Light

The radiated energy per unit frequency (cgs units) is

$$\frac{dI(\omega)}{dx} = \frac{e^2\omega}{c^2}[1 - \frac{1}{\beta^2\epsilon(\omega)}] \tag{1}$$

We convert to the number of photons by dividing by $\hbar\omega$

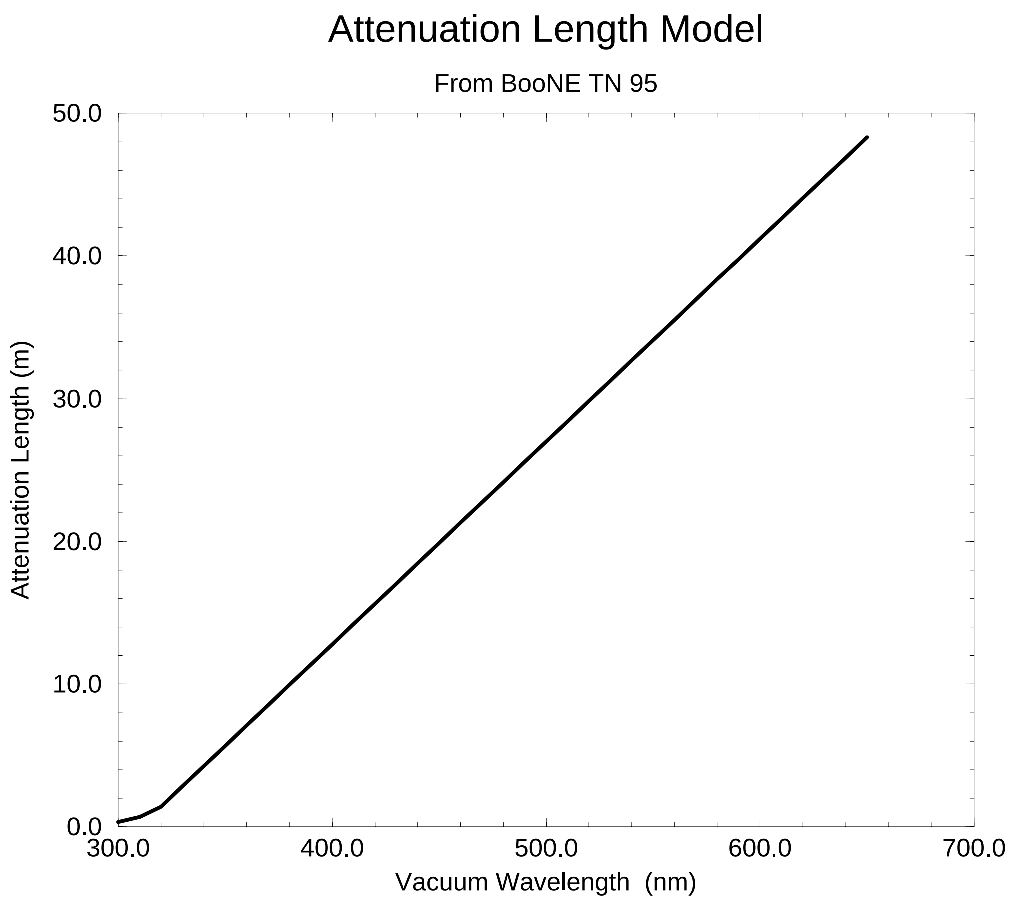
$$\frac{dN(\omega)}{dx} = \frac{e^2}{\hbar c^2}[1 - \frac{1}{\beta^2\epsilon(\omega)}] \tag{2}$$

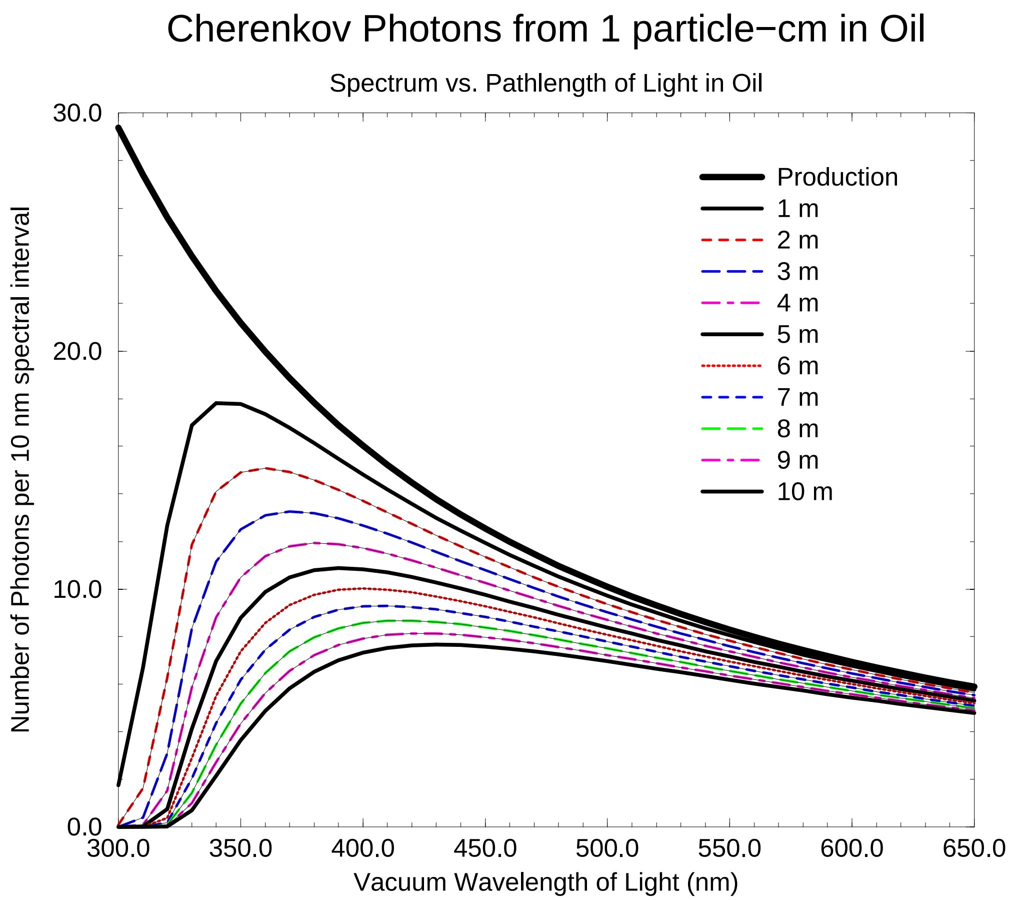
and integrating this [while neglecting the dependence of ϵ on ω], we have photons in an interval from ω_1 to ω_2

$$\frac{dN}{dx} = \frac{e^2}{\hbar c^2}[1 - \frac{1}{\beta^2\epsilon(\omega)}][\omega_2 - \omega_1] \tag{3}$$

We note that $\epsilon(\omega) = n^2(\omega)$ and $\alpha = \frac{e^2}{\hbar c^2} \sim \frac{1}{137}$ so that converting to (vacuum) wavelength in place of frequency we have

$$\frac{dN}{dx} = 2\pi\alpha[\frac{1}{\lambda_2} - \frac{1}{\lambda_1}][1 - \frac{1}{\beta^2 n^2(\lambda)}] \tag{4}$$


Attenuation Length Model
From BooNE TN 95
50.0
40.0
30.0
20.0
10.0
0.0
Attenuation Length (m)
300.0
400.0
500.0
600.0
700.0
Vacuum Wavelength (nm)



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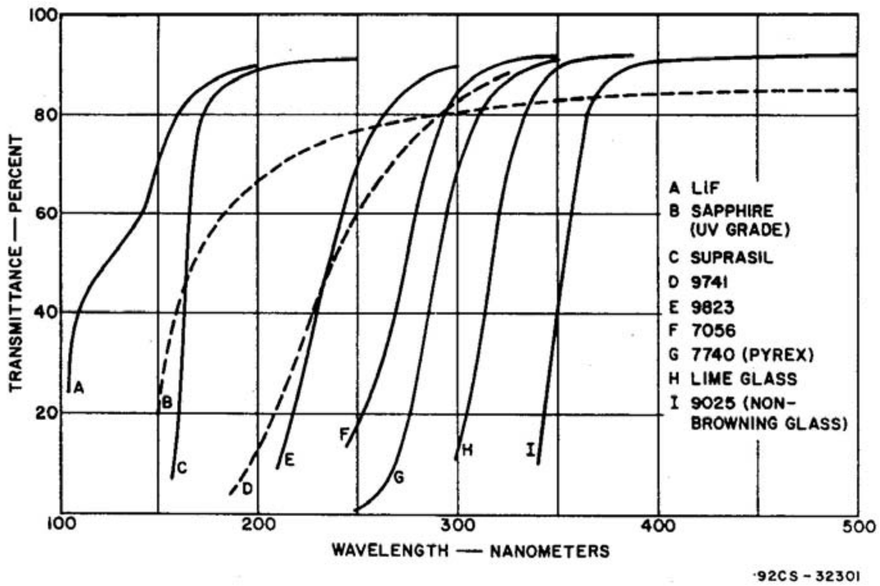

Fig. 15 - Ultraviolet transmittance cut off of various glasses and crystals used in photomultiplier photocathode windows. Data are all for 1 mm thickness.

18

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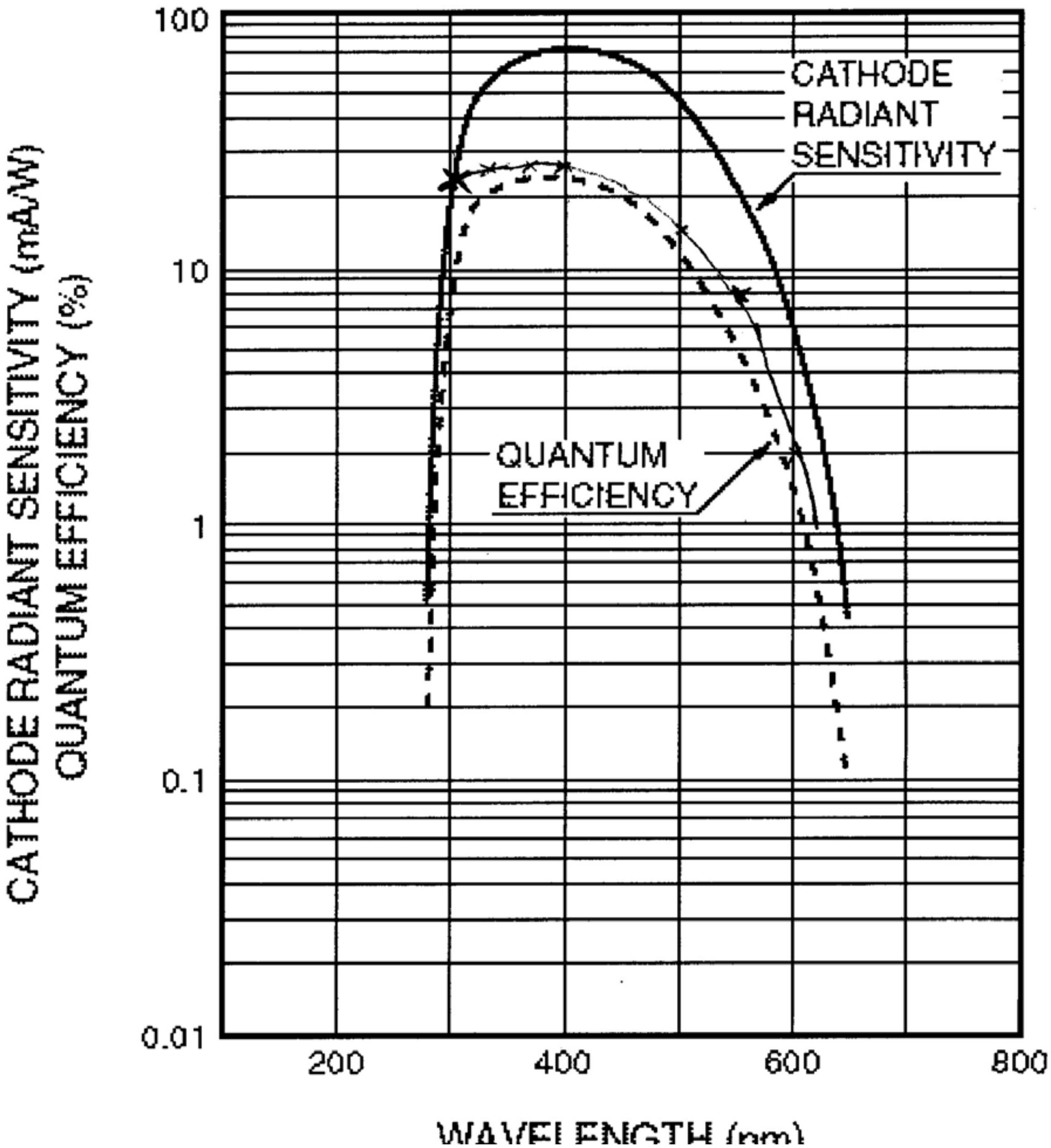
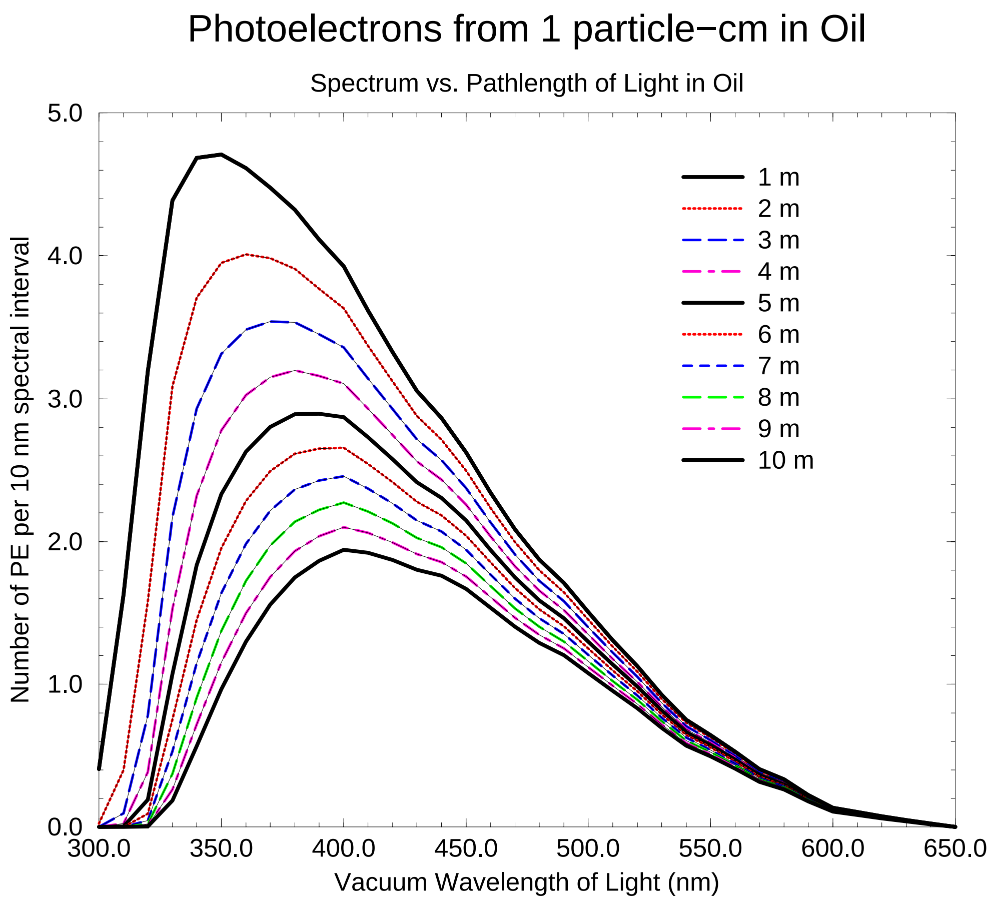
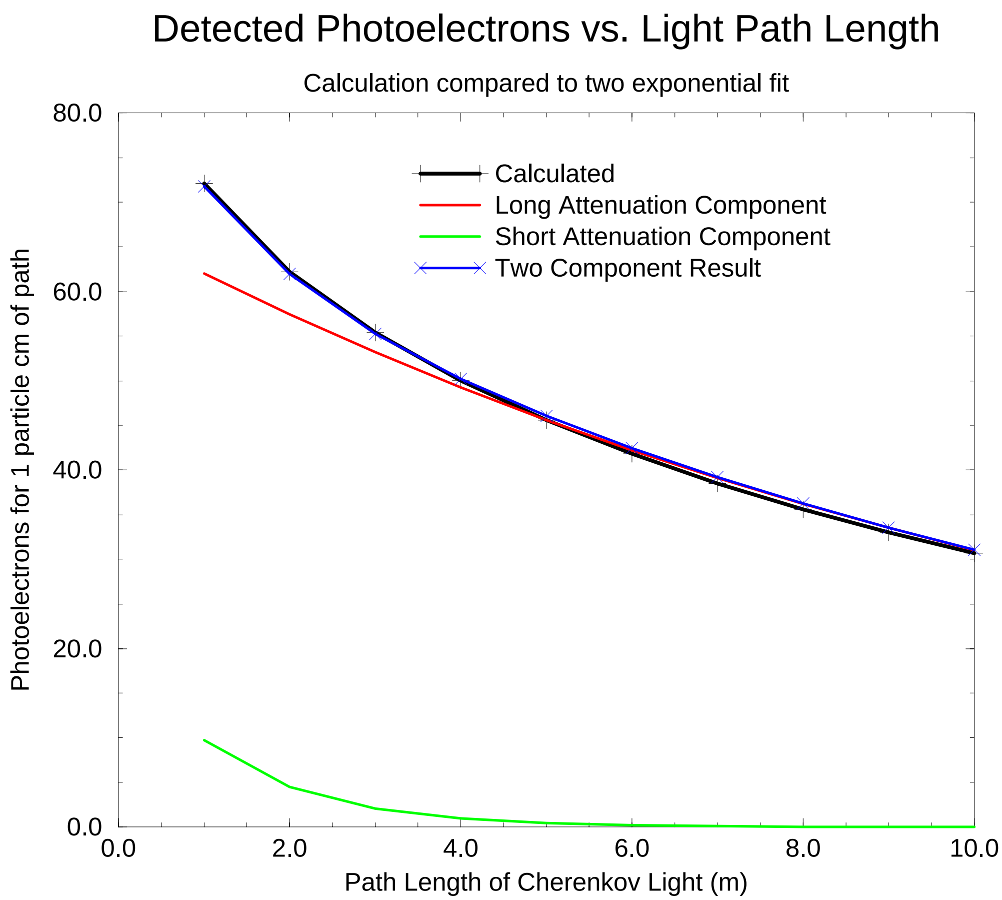

100
10
1
0.1
0.01
200
400
600
800
CATHODE
RADIANT
SENSITIVITY
QUANTUM
EFFICIENCY
CATHODE RADIANT SENSITIVITY (mA/W)
QUANTUM EFFICIENCY (%)
WAVELENGTH (nm)



Photoelectrons from 1 particle−cm in Oil
Spectrum vs. Pathlength of Light in Oil
Number of PE per 10 nm spectral interval
Vacuum Wavelength of Light (nm)
0.0
1.0
2.0
3.0
4.0
5.0
300.0
350.0
400.0
450.0
500.0
550.0
600.0
650.0
1 m
2 m
3 m
4 m
5 m
6 m
7 m
8 m
9 m
10 m



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Observations

- Calculations which include the polarization of Cherenkov Light may be required to properly understand scattering.

- Angular differences in the produced light due to the dispersion in oil are unlikely to be important but should be considered.

- Although most of the energy emitted as Cherenkov light will be detected in the cone, some of the very short wavelength light will be absorbed and re-emitted near the source and will be distributed isotropically. We have some measurements of the spectral characteristics of this fluorescence but we need to learn if it has the 19 ns decay characteristic of the scintillation or perhaps a different (or more than one different) fluorescence lifetime. We also need to determine the fluorescence yield from this process.

Observation (continued)

- At some point we will need to review the effects of the difference between the TN-090 index of refraction and other measurements on yield (small) and geometry (to be reviewed) and settle what values are to be used in the analysis and Monte Carlo programs. The temperature correction from 20^o C to the tank temperature should be done but variations in temperature during running are surely not significant. A future TN should document how we handle this.

Conclusions

- The fitting algorithms should employ an attenuation model for Cherenkov light with two attenuation lengths

$$N(x) = N_0\alpha\, e^{-(\frac{x}{L_{A1}})} + N_0(1-\alpha)e^{-(\frac{x}{L_{A2}})} \tag{5}$$

where L_{A1}, L_{A2}, α can all be fixed inputs to the fitting.

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